The Expert System Design to Identify Laptop Damage by Applying Certainty Factor Method

Luh Gede Astuti [a]
Gede Aditya Mahardika Pratama [b]

Article history:	Abstract
	The development of information technology nowadays is very useful in solving problems in an activation process. One of the existing technological developments is the emergence of portable computers in the form of laptops. The problem of laptop damage is the most common case, so a good knowledge of laptops is needed to anticipate laptop damage. Applications that can help deal with the problem of damage to the laptop are the Expert System. An expert system is a system that seeks to adopt human knowledge to computers, to solve problems as usually done by experts. In overcoming uncertainty in an expert system, the Certainty Factor (CF) method is applied. Certainty Factor (Uncertainty Factor) is a method that expresses belief in an event (fact or hypothesis) based on evidence or expert judgment. This study develops an expert system to identify laptop damage with a certainty factor in the form of a web-based application. Blackbox is used as a system test and gives results that the developed expert system can function properly and has been running according to its functionality. *International research journal of engineering, IT & scientific research © 2021.*

Corresponding author:
Luh Gede Astuti,
Informatics Department, Udayana University, Denpasar, Indonesia.
Email address: lg.astuti@unud.ac.id

---

[a] Informatics Department, Udayana University, Denpasar, Indonesia
[b] Informatics Department, Udayana University, Denpasar, Indonesia

1 Introduction

Advances in computer technology are currently developing very rapidly, technology has given a very important influence in everyday life where almost all activities carried out cannot be separated from technology, especially computer technology. With the rapid development of computer technology, computer inventors and developers have been looking for various ways to make it easier for users to use it, one of which is a laptop. Parts or components of laptop hardware within a certain period will experience physical changes or damage, which causes the laptop to be repaired. Therefore, it is highly recommended for users to know how to care for and provide first aid when their laptop has a problem, before deciding to hand it over to a service center. Information that is expected to be able to overcome the damage that occurs today is still incomplete, even the included manual cannot accommodate all possible damage, therefore it is felt that an application (software) is needed to help solve the problem of damage to laptop hardware. One system that can be used to overcome this is expert.

An expert system is a system that seeks to adopt human knowledge to computers, to solve problems as is usually done by experts (Liao, 2005; González-Andújar, 2009). Many studies have been carried out using expert systems, because as we all know that information technology has entered into all fields, not only in the field of computers. This expert system was intended to replace the role of an expert (Rahman, 2020). With this expert system, ordinary people can solve their problems or just look for quality information that can only be obtained with the help of experts in their fields. This expert system can also help the activities of experts as experienced assistants and have the required knowledge (Santi & Andari, 2019; Ebersbach & Peng, 2008).

In an expert system, there can be uncertainty or a problem because it may prevent us from making the best decision, it may even result in a bad decision. One method that can be used to overcome uncertainty is the Certainty Factor (CF) (Azareh et al., 2019; Lucas, 2001). Certainty Factor (Uncertainty Factor) is a method that expresses belief in an event (fact or hypothesis) based on evidence or expert judgment. Several studies that use an expert system with the CF method include research on identifying facial skin types (Rahman, 2020), diagnosing renal tubular acidosis with forwarding chaining (Santi & Andari, 2019), and diagnosing elephantiasis (Fanny et al., 2017). From the above description, this research will establish an expert system that can be used to determine or identify the type of computerized laptop damage. In this study, the certainty factor method will be used to solve expert system problems that contain uncertainty (Wang et al., 2020; Mahoney & Mooney,1994). The result of this research is a web-based application that can detect and trace laptop damage problems based on the symptoms experienced by the laptop user.

2 Materials and Methods

The expert system

The expert system is part of artificial intelligence (AI) which is quite old because this system was developed in 1960. The expert system that first appeared as the General Purpose Problem Solver (GPS) was developed by Newel Simon (Hasibuan et al., 2017). The term expert system is from the term knowledge-based expert system. An expert system uses the knowledge of an expert that is entered into a computer. A non-expert/expert uses an expert system to improve problem-solving skills, while an expert uses an expert system for knowledge assistants (Sulistyohati & Hidayat, 2008).

There are two important parts to an expert system, they are, the development environment and the consulting environment (Singh, 2017). The development environment is used by the manufacture of the expert system to build its components and introduce knowledge into the knowledge base. The consulting environment is used by the user to consult so that the user gets knowledge from the expert system such as consulting an expert (Sulistyohati & Hidayat, 2008).

Certainty factor

Certainty Factor (CF) is a method proposed by Shortliffe and Buchanan in 1975 to accommodate the inexact reasoning of an expert. An expert (eg doctor) often analyzes information with the expressions "probably", "most likely", "almost certain". So with the Certainty Factor method, it can describe the level of confidence of an expert on the problem at hand (Sulistyohati & Hidayat, 2008). Certainty Factor expresses belief in an event (fact or hypothesis)

based on evidence or expert judgment. Certainty Factor uses a value to assume the degree of confidence of an expert in data. Certainty Factor introduces the concept of belief and disbelief (Santi & Andari, 2019). In its application, there are two values used to obtain the Certainty Factor value, namely CF(H,E) and CF(E,e). CF(H,E) is the value of certainty given by the expert to a rule, while CF(E,e) is the value of trust given by the user to the symptoms he experiences. The following is the formula for the Certainty Factor method to assume the certainty of an expert on data (Santi & Andari, 2019).

$$CF[H,E] = CF[H] * CF[E] \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$
$$CF_{combine} \; CF[H,E]_{1,2} = CF[H,E]_1 + CF[H,E]_2 * (1 - CF[H,E]_1)\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(2)$$
$$CF_{combine} \; CF[H,E]_{old,3} = CF[H,E]_{old} + CF[H,E]_2 * (1 - CF[H,E]_{old})\dots\dots\dots\dots\dots\dots\dots\dots(3)$$

Remark:
CF = Certainty Factor in H hypotheses which influenced by E fact.
E = Evidence (Peristiwa atau Fakta).

3   Results and Discussions

3.1 Data analysis and system needed

Before developing an expert system, data collection stages will be carried out which will be used to establish a knowledge base. The data applied is secondary data in the form of a collection of laptop damage cases obtained from a journal written by Harif A. Rahman with the title "Expert System in Detecting Laptop Damage with Case-Based Reasoning Methods" (Aji et al., 2017). To support this research, other data were also collected based on reference books and the results of previous similar studies. The data analysis phase and system requirements are carried out after the data collection stage is completed. From this stage can be analyzed and compiled system requirements needed in building an expert system. The results of data collection obtained 7 types of damage to the laptop, namely damage to the fan, damage to the hard disk, damage to the processor, damage to the screen, damage to the operating system, damage to USB, and damage to charging. Meanwhile, a collection of one's problems regarding the damage to the laptop experienced is included in the symptom data. Symptom data is used as a reference in identifying the type of laptop damage. Symptom data obtained from all types of damage contained 44 symptom

After obtaining the type of laptop damage and its symptoms, it will be continued with the design of the knowledge base. In designing the knowledge base, the production rules are written in the form of an IF [premise] THEN [conclusion] statement. In designing this expert system knowledge base, the premise is a symptom and the conclusion is a type of laptop damage, so the form of the statement is IF [symptom] THEN [type of laptop damage]. In this expert system in one rule there can be more than one symptom. Also, the symptoms are connected by using the logical AND operator. At this stage, the weighting process will also be carried out. The weighting value on CF was obtained from the expert by giving a value of 0 for unsure, 0.4 for unsure, 0.6 for fairly sure, 0.8 for sure, and 1 for very sure. Based on the type of damage and symptoms obtained and giving weights to the CF method, it can be done by grouping the type of laptop damage data and symptoms according to the damage as seen in Tables 1 to 7.

Table 1
Symptoms of damage to the fan

No	Id	Symptoms	Expert Weight
1	G01	Laptop often hang	0.6
2	G02	The fan temperature is not in good condition	0.6
3	G03	Laptop is easily heated	0.4
4	G04	Laptop often overheated	0.8
5	G05	The fan is noisy	0.8
6	G06	There is wind at the exhaust	0.6
7	G07	Laptop often shut down suddenly	0.4
8	G08	Laptop fan is not circulating	0.4
9	G09	Keyboard is not working	0.8

Table 2
Symptoms of damage on harddisk

No	Id	Symptom	Expert Weight
1	G10	There are bizarre code	0.8
2	G11	Error code shown on laptop	0.8
3	G12	Hardisk overhearted	0.6
4	G13	Hardisk easily heated	0.6
5	G14	Data is often unread	0.6
6	G15	Blue Screen	0.6

Table 3
Damage symptoms in processor

No	Id	Symptoms	Expert Weight
1	G01	laptop often hang	0.6
2	G03	Laptop easily heated	0.4
3	G07	Laptop often shut down suddenly	0.4
4	G15	Blue Screen	0.6
5	G16	Laptop is not working	0.6
6	G18	Failure in opening programs	0.6
7	G19	Sistem is only on temporarily	0.6
8	G20	Booting failure is often	0.8

Table 4
Damage symptoms on screen

No	Id	Symptoms	Expert Weight
1	G21	The screen is shaking	0.4
2	G22	There is gomy	0.6
3	G23	Lined LCD	0.8
4	G24	LCD displays artifact	0.8
5	G25	Blank LCD	0.4

Table 5
Damage system in the operational system

No	Id	Symptoms	Expert Weight
1	G26	Booting stop after POST	0.4
2	G27	Booting to windows runs slowly	0.6
3	G28	Windows explorer is not active	0.6
4	G29	Start menu is not working	0.8
5	G30	Shut down procedure is not running	0.8
6	G31	Shutdown procedure stop before computer stop	0.6
7	G32	The screen is always silent	0.6

Table 6
Damage symptom on USB

No	Id	Symptoms	Expert Weight
1	G33	Driver uninstalled	0.4
2	G34	Loose USB Port	0.8
3	G35	Broken USB Port	0.6
4	G36	USB stripe on PCB disconnected	0.6
5	G37	Disable USB Selective	0.8

Table 7
Damage symptoms on charging

No	Id	Symptoms	Expert Weight
1	G03	Laptop is easily heated	0.4
2	G38	Problem on charger plug	0.8
3	G39	Problem in laptop charger	0.6
4	G40	Problem in charger adapter	0.6
5	G41	Problem in charger cable connection	0.8
6	G42	Problem in connector tip	0.6
7	G43	Problem in charger port	0.8
8	G44	Cross signal on battery picture	0.8

3.2 Example of calculation

In this example case, the symptoms experienced by the user and the user weight values will be shown in table 8.

Table 8
Symptoms experienced by a user

No	Id	Symptoms	User weight	Description
1	G01	Laptop often hang	0.6	Quite sure
2	G03	Laptop easily heated	0.8	Sure
3	G04	Laptop often overheated	0.6	Quite Sure
4	G05	The fan is noisy	0.4	A little sure
5	G07	Laptop is often shut down suddenly	0.8	Sure

If the symptoms and user weight values have been determined, then proceed with the calculation using equation 1. The calculation is done by multiplying the user weight value by the expert weight value in tables 1 to 7. The calculation results can be seen in table 9.

Table 9
Calculation of user weight with expert weight

No	Id	Symptoms	User weight	Expert Weight	User weight * expert weight
1	G01	Laptop often hang	0.6	0.6	0.36
2	G03	Laptop is easily heated	0.8	0.4	0.32
3	G04	Laptop often overheated	0.6	0.8	0.48
4	G05	The fan is very noisy	0.4	0.8	0.32
5	G07	Laptop often shut down suddenly	0.8	0.4	0.32

Furthermore, the CF combine calculation will be carried out using equations 2 and 3. The calculation will be carried out on all types of damage according to the symptoms of the damage. The following is the calculation of the CF combine:

a. CF combine kerusakan pada Fan

$$CF(H,E)_{G01,G02} = CF_{G01} + CF_{G02} * (1 - CF_{G01})$$
$$= 0.36 + 0 * (1 - 0.36) = 0.36$$
$$CF(H,E)_{old1,G03} = CF_{old1} + CF_{G03} * (1 - CF_{old1})$$
$$= 0.36 + 0.32 * (1 - 0.36) = 0.56$$
$$CF(H,E)_{old2,G04} = CF_{old2} + CF_{G04} * (1 - CF_{old2})$$
$$= 0.56 + 0.48 * (1 - 0.56) = 0.77$$

Astuti, L. G., & Pratama, G. A. M. (2021). The expert system design to identify laptop damage by applying certainty factor method . International Research Journal of Engineering, IT & Scientific Research, 7(4), 165-175.
https://doi.org/10.21744/irjeis.v7n4.1898

$CF(H,E)_{old3,G05}$ $= CF_{old3} + CF_{G05} * (1 - CF_{old3})$
                      $= 0.77 + 0.32 * (1 - 0.77) = 0.84$

$CF(H,E)_{old4,G06}$ $= CF_{old4} + CF_{G06} * (1 - CF_{old4})$
                      $= 0.84 + 0 * (1 - 0.84) = 0.84$

$CF(H,E)_{old5,G07}$ $= CF_{old5} + CF_{G07} * (1 - CF_{old5})$
                      $= 0.84 + 0.32 * (1 - 0.84) = 0.9$

$CF(H,E)_{old6,G08}$ $= CF_{old6} + CF_{G08} * (1 - CF_{old6})$
                      $= 0.9 + 0 * (1 - 0.9) = 0.9$

$CF(H,E)_{old7,G09}$ $= CF_{old7} + CF_{G09} * (1 - CF_{old9})$
                      $= 0.9 + 0 * (1 - 0.9) = 0.9$

b.   CF combine damage in processor

$CF(H,E)_{G01,G03}$ $= CF_{G01} + CF_{G03} * (1 - CF_{G01})$
                      $= 0.36 + 0.32 * (1 - 0.36) = 0.56$

$CF(H,E)_{old1,G07}$ $= CF_{old1} + CF_{G07} * (1 - CF_{old1})$
                      $= 0.56 + 0.32 * (1 - 0.56) = 0.70$

$CF(H,E)_{old2,G15}$ $= CF_{old2} + CF_{G15} * (1 - CF_{old2})$
                      $= 0.70 + 0 * (1 - 0.70) = 0.70$

$CF(H,E)_{old3,G16}$ $= CF_{old3} + CF_{G16} * (1 - CF_{old3})$
                      $= 0.70 + 0 * (1 - 0.70) = 0.70$

$CF(H,E)_{old4,G18}$ $= CF_{old4} + CF_{G18} * (1 - CF_{old4})$
                      $= 0.70 + 0 * (1 - 0.70) = 0.70$

$CF(H,E)_{old5,G19}$ $= CF_{old5} + CF_{G19} * (1 - CF_{old5})$
                      $= 0.70 + 0 * (1 - 0.70) = 0.70$

$CF(H,E)_{old6,G20}$ $= CF_{old6} + CF_{G20} * (1 - CF_{old6})$
                      $= 0.70 + 0 * (1 - 0.70) = 0.70$

c.   CF combine damage in Charging

$CF(H,E)_{G03,G38}$ $= CF_{G03} + CF_{G38} * (1 - CF_{G03})$
                      $= 0.32 + 0 * (1 - 0.32) = 0.32$

$CF(H,E)_{old1,G39}$ $= CF_{old1} + CF_{G39} * (1 - CF_{old1})$
                      $= 0.32 + 0 * (1 - 0.32) = 0.32$

$CF(H,E)_{old2,G40}$ $= CF_{old2} + CF_{G40} * (1 - CF_{old2})$
                      $= 0.32 + 0 * (1 - 0.32) = 0.32$

$CF(H,E)_{old3,G41}$ $= CF_{old3} + CF_{G41} * (1 - CF_{old3})$
                      $= 0.32 + 0 * (1 - 0.32) = 0.32$

$CF(H,E)_{old4,G42}$ $= CF_{old4} + CF_{G42} * (1 - CF_{old4})$
                      $= 0.32 + 0 * (1 - 0.32) = 0.32$

$CF(H,E)_{old5,G43}$ $= CF_{old5} + CF_{G43} * (1 - CF_{old5})$
                      $= 0.32 + 0 * (1 - 0.32) = 0.32$

$CF(H,E)_{old6,G44}$ $= CF_{old6} + CF_{G44} * (1 - CF_{old6})$
                      $= 0.32 + 0 * (1 - 0.32) = 0.32$

The results of the CF combine calculation on the type of damage to the Hard Drive, Screen, Operating System and USB are 0 because the symptoms experienced by the user in table 9 are not symptoms of these damages. And based on the results of calculations using the CF method above, the CF combined value of the Fan damage is 0.9, the damage to the Processor is 0.70 and the damage to Charging is 0.32. So that the type of damage based on the symptoms experienced by the user is the damage that has the largest CF value, namely, damage to the Fan with a value of 0.9 or 90%.

3.3 System implementation

In this research, an expert system with certainty factor on laptop damage diagnosis is implemented by building a web-based application. Application development is carried out using HTML, PHP, CSS, Javascript, Bootstrap

Framework, and MySQL programming languages. Before making the application, the database will be formed which is used to manage knowledge base data and also store data in the application. The database design is shown in Figure 1.
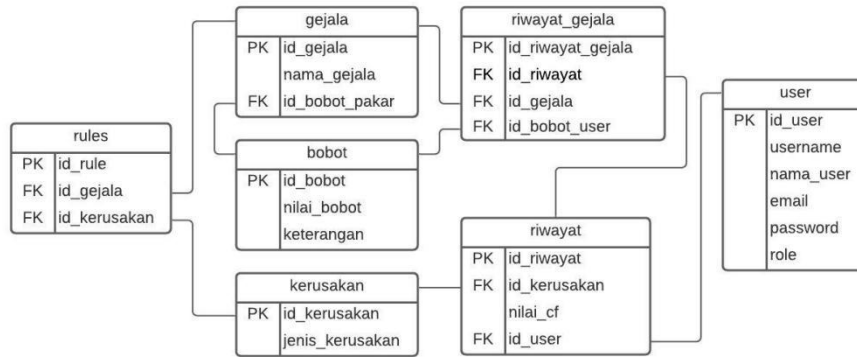

Figure 1. Database design

Next, the application design will be carried out, the established application have several main features made, namely login forms, dashboards, consultations, consultation results, symptom lists, damage lists, rule base lists, consultation history, and admin lists. Here are some views of the user interface of the features made.

a) Dashboard Page
   The dashboard page is the main page display of the application. This page displays all menus available in this application.

Figure 2. Dashboard page

b) Consultation Page
   The consultation page is used by the user to conduct consultations on the damage to the laptop experienced by the user. The user can choose the weight value for each symptom experienced by the user.
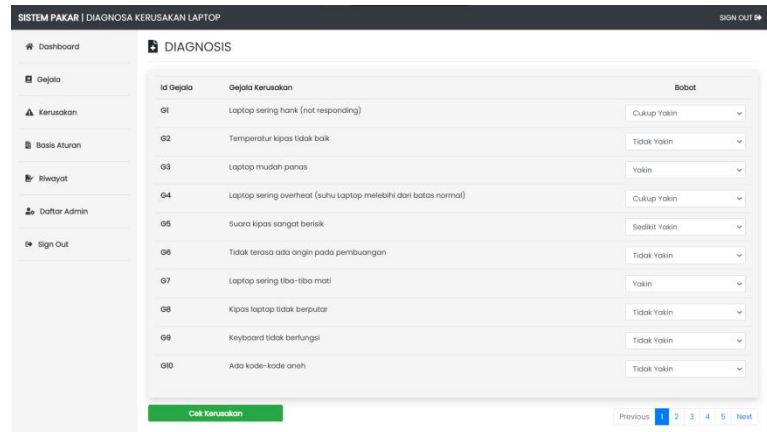
Figure 3. Diagnosis page

c) Consultation Result Page
Consultation Result Page is used to give the consultation result from the CF calculation result based on the symptoms and also the weight that has been input by users.
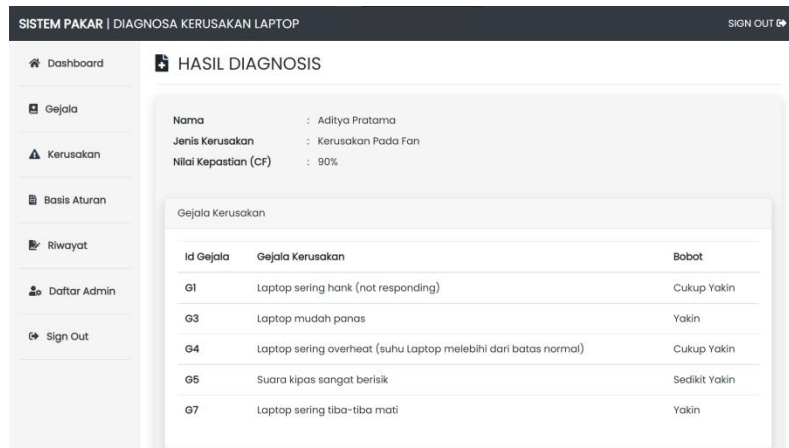

Figure 4. Diagnosis result page

3.4 System testing

System testing is done by using BlackBox testing. Blackbox is used to test the functionality of the expert system to identify damage to the laptop that is being built, where this test is carried out by running the menus on the expert system website and seeing the output generated by the system based on the input conditions given for each function on the system. The results of the BlackBox test are presented in Table 10 and Table 11.

Table 10
Black box testing on the user page

No	Tested feature	Testing scenario	Expected Result	Testing Result
1	Login form	Enter username and password	User is directed to dashboard page	Appropriate
2	Register form	Enter username, nama, email, and password	New account and directed to login form page	Appropriate
3	Dashboard	Access all available menu	User is directed to selected menu	Appropriate
4	Consultation and	Consult by entering weight of	User is directed to consultation	Appropriate

		every symptoms	report page and is given type of damage and the certainty value	
	result of consultation			
5	Symptom List	-	Users can see all symptoms	Appropriate
6	Damage List	-	Users can see all types of damage	Appropriate
7	Rule Base List	-	Users can see all available rule basis	Appropriate
8	Consultation History	To see consultation list and delete consultation list	The user is directed to the consultation detail page and can delete the consultation list	Appropriate
9	Sign Out	-	The user is directed to the login form page	Appropriate

Table 11
Black box testing on the administration page

No	Testing Feature	Testing Scenario	Expected Result	Testing Result
1	Login form	Enter username and password	Admin is directed to dashboard page	Appropriate
2	Dashboard	Access available menu	Admin is directed to page according to selected menu	Appropriate
3	Consultation and Consultation Result	Conducting consultation by including the weight of every symptom	Admin is directed to result in consultation page and given type of damage and also the value of certainty	Appropriate
4	Symptom List	Add, change and delete symptoms	Admin can add new symptom, change and delete symptom	Appropriate
5	Damage List	Add, change and delete types of damage	Admin can add new damage, change and delete type of damage	Appropriate
6	Rule Base List	Add, change and delete rule basis	Admin can add a new rule, change and delete rule base	Appropriate
7	Consultation History	Ablet to see list of consultation and delete consultation list	Admin is directed to a page of consultation detail and can delete the consultation list	Appropriate
8	Admin List	Add and delete admin	Admin can add new admin and delete admin	Appropriate
9	Sign Out	-	Admin is directed to login form	Appropriate

Based on the results of BlackBox testing on the functionality of the login form page, dashboard, consultation, consultation results, symptom list, damage list, rule base list, consultation history, and admin list, it can be concluded that the expert system applied for identifying laptop damage with Certainty Factor method has been running according to with its functionality or concluded to have the conformity of 100%, namely the test results are as expected (Olden & Jackson, 2002; Kadefors, 2004; Wood et al., 2009).

4 Conclusion

Based on the results of research and discussions that have been carried out, it can be concluded that:
a) The expert system application to identify laptop damage is an application to identify laptop damage based on knowledge from experts or the symptoms contained in the rule.
b) The confidence value generated from this system is the same as the result of manual calculations using the Certainty Factor calculation. So that the accuracy of the results is following the expected calculations.
c) This expert system application can be a means to store knowledge about the types of laptop damage from experts or experts.

d) From the results of the Blackbox test, it can be concluded that the expert system can function properly and has been running according to its functionality.

References

Aji, A. H., Furqon, M. T., & Widodo, A. W. (2017). Sistem Pakar Diagnosa Penyakit Ibu Hamil Menggunakan Metode Certainty Factor (CF). *Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer, ISSN*, *2*(5), 27-36.

Azareh, A., Rahmati, O., Rafiei-Sardooi, E., Sankey, J. B., Lee, S., Shahabi, H., & Ahmad, B. B. (2019). Modelling gully-erosion susceptibility in a semi-arid region, Iran: Investigation of applicability of certainty factor and maximum entropy models. *Science of the Total Environment*, *655*, 684-696. https://doi.org/10.1016/j.scitotenv.2018.11.235

Ebersbach, S., & Peng, Z. (2008). Expert system development for vibration analysis in machine condition monitoring. *Expert systems with applications*, *34*(1), 291-299. https://doi.org/10.1016/j.eswa.2006.09.029

Fanny, R. R., Hasibuan, N. A., & Buulolo, E. (2017). Perancangan Sistem Pakar Diagnosa Penyakit Asidosis Tubulus Renalis Menggunakan Metode Certainty Factor Dengan Penulusuran Forward Chaining. *Jurnal Media Informatika Budidarma*, *1*(1).

González-Andújar, J. L. (2009). Expert system for pests, diseases and weeds identification in olive crops. *Expert Systems with Applications*, *36*(2), 3278-3283. https://doi.org/10.1016/j.eswa.2008.01.007

Hasibuan, N. A., Sunandar, H., Alas, S., & Suginam, S. (2017). Sistem Pakar Mendiagnosa Penyakit Kaki Gajah Menggunakan Metode Certainty Factor. *Jurasik (Jurnal Riset Sistem Informasi Dan Teknik Informatika)*, *2*(1), 29-39.

Kadefors, A. (2004). Trust in project relationships—inside the black box. *International Journal of project management*, *22*(3), 175-182. https://doi.org/10.1016/S0263-7863(03)00031-0

Liao, S. H. (2005). Expert system methodologies and applications—a decade review from 1995 to 2004. *Expert systems with applications*, *28*(1), 93-103. https://doi.org/10.1016/j.eswa.2004.08.003

Lucas, P. J. (2001). Certainty-factor-like structures in Bayesian belief networks. *Knowledge-based systems*, *14*(7), 327-335. https://doi.org/10.1016/S0950-7051(00)00073-3

Mahoney, J. J., & Mooney, R. J. (1994). Comparing methods for refining certainty-factor rule-bases. In *Machine Learning Proceedings 1994* (pp. 173-180). Morgan Kaufmann. https://doi.org/10.1016/B978-1-55860-335-6.50029-5

Olden, J. D., & Jackson, D. A. (2002). Illuminating the "black box": a randomization approach for understanding variable contributions in artificial neural networks. *Ecological modelling*, *154*(1-2), 135-150. https://doi.org/10.1016/S0304-3800(02)00064-9

Rahman, H. A. (2020). Sistem Pakar dalam Mendeteksi Kerusakan Laptop dengan Metode Case Based Reasoning. *Jurnal Sistim Informasi dan Teknologi*, 71-76.

Santi, I. H., & Andari, B. (2019). Sistem pakar untuk mengidentifikasi jenis kulit wajah dengan metode certainty factor. *INTENSIF: Jurnal Ilmiah Penelitian dan Penerapan Teknologi Sistem Informasi*, *3*(2), 159-177.

Singh, S. (2017). Multi-factor authentication and their approaches. *International Research Journal of Management, IT and Social Sciences*, *4*(3), 68-81.

Sulistyohati, A., & Hidayat, T. (2008). Aplikasi sistem pakar diagnosa penyakit ginjal dengan metode DEMPSTER-SHAFER. In *Seminar Nasional Aplikasi Teknologi Informasi (SNATI)* (Vol. 1, No. 1).

Wang, J., Zhu, S., Luo, X., Chen, G., Xu, Z., Liu, X., & Li, Y. (2020). Refined micro-scale geological disaster susceptibility evaluation based on UAV tilt photography data and weighted certainty factor method in Mountainous Area. *Ecotoxicology and environmental safety*, *189*, 110005. https://doi.org/10.1016/j.ecoenv.2019.110005

Wood, T., Shenoy, P., Venkataramani, A., & Yousif, M. (2009). Sandpiper: Black-box and gray-box resource management for virtual machines. *Computer Networks*, *53*(17), 2923-2938. https://doi.org/10.1016/j.comnet.2009.04.014